Housing for the North-- The Stackwall System

Construction Report--
Mildred Lake Tank and Pump House

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ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

RESEARCH REPORTS

These research reports describe the results of investigations funded under the Alberta Oil Sands Environmental Research Program, which was established by agreement between the Governments of Alberta and Canada in February 1975. AOSERP is a 10-year Program designed to direct and coordinate research projects into the environmental effects of the development of the Athabasca oil sands in Alberta.

Enquiries pertaining to the Alberta-Canada Agreement or requests for copies of the research reports should be directed to:

Alberta Oil Sands Environmental Research Program
Penthouse, Jarvis Building
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Edmonton, Alberta T5K 2H9
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Housing for the North--The Stackwall System
Construction Report--Mildred Lake Tank and Pump House

AOSERP Report 6

LETTER OF TRANSMITTAL

The Hon. D. J. Russell
Minister of the Environment
222 Legislative Buildings
Edmonton, Alberta

and

The Hon. R. Le Blanc
Minister of Fisheries and Environment
Parliament Buildings
Ottawa, Ontario

Sirs:

Enclosed herein is the report on "Housing for the North--The Stackwall System; Construction Report--Mildred Lake Tank and Pump House".

This report was prepared for Program Management of the Alberta Oil Sands Environmental Research Program, who provided funding for the structure, under the Alberta-Canada Agreement of 28 February 1975.

Respectfully,

W. Solodzuk, P.Eng.
Chairman, Steering Committee, AOSERP
Deputy Minister, Alberta Environment

for J. S. Tener, Ph.D.
Member, Steering Committee, AOSERP
Assistant Deputy Minister
Environmental Management Service
Environment Canada

Housing for the North - The Stackwall System

Construction Report - Mildred Lake Tank and Pump House

DESCRIPTIVE SUMMARY

ABSTRACT

The Alberta Oil Sands Environmental Research Program (AOSERP) conducted the first "Stackwall" housing research in Alberta, 30 miles north of Fort McMurray. It contracted with the Northern Housing Committee of the University of Manitoba to design and supervise the construction of a "Stackwall" structure to house the 5,000 gallon potable water tank for the AOSERP research facility at Mildred Lake, Alberta. Most of the work was done by native people of the Fort McMurray area as a training project.

Construction was done during the cold weather of November and December 1975. The final outside dimensions of the building are 32 x 16 x 9 feet.

The Stackwall method is to lay two-foot log lengths side-by-side, and mortar them in place to form a permanent log pile. (Photographs 6 and 7.) Wood shavings are added between the log layers to improve the insulation. Logs of various diameters can be randomly placed, thereby eliminating waste of materials or time.

The advantages of the Stackwall construction include:

1. Lower heating costs due to the high insulation value of the walls.
2. The intensive use of relatively unskilled labor.
3. The use of locally available non-commercial wood products and sand for mortar.

The building was instrumented to determine heat retention and ease of heating. The insulating ability (or thermal resistance) of the building was found to rate at least R 18, which is about equivalent to a 6" thick glass or mineral fiber insulation batt.

The AOSERP report outlines the construction phases, describes and analyzes the techniques unique to the construction, calculates certain parameters and details all costs and specifications for the Mildred Lake structure. The total cost was $10,960.20 which included $6,685.85 for labor. Thus, if a person built it on his own during warmer weather the cost would be very low.

BACKGROUND AND PERSPECTIVE

The absence of a usable potable groundwater source in the oil sands area dictated that water be hauled and stored for use at the AOSERP Mildred Lake research facility. When a pressure system in addition to water storage is required, the locally accepted method is to construct an insulated shelter.

The Alberta Oil Sands Environmental Research Program's need for a water tank shelter paralleled the Northeast Alberta Region Commissioner's interest in having a prototype Stackwall structure in the Fort McMurray area. The Stackwall construction method could contribute to lowering the cost of housing by providing an opportunity for people relatively unskilled in house-building to combine "sweat or muscle equity" with low or no cost logs, available locally, to build their own homes. These combinations are in abundant supply in northern Canada, whereas the resources required to construct and maintain conventional southern Canada housing are not. The Human Environment Technical Research Committee of AOSERP secured the involvement of local native and Metis organizations. This, combined with the interest of the Northeast Alberta Region Commissioner and the need for a structure to keep the water supply from freezing, resulted in the use of the Stackwall system for the tank and pump house at the AOSERP research facility. The finished building is shown in Picture 17.

ASSESSMENT

In the opinion of all who participated in its construction and of the many interested observers, the experiment has been a success. It demonstrated the ease and economy of construction, the insulating capability of the Stackwall building, the durability, and overall attractiveness of the construction type.

This project has contributed in a small way to a more rational and practical approach to comfortable housing in northern Canada by demonstrating a technique and creating a prototype in a high housing demand area that:

i) provides the opportunity for reasonable-cost housing to people whose contributions may be largely limited to their own physical effort

ii) utilizes the locally available non-commercial wood resource, and

iii) conserves heat energy.

This experiment in innovative construction methods, suited to the northern climate and using local materials, was conducted to establish a prototype in the Fort McMurray area. After one full year's service, it has been deemed a success and is being copied in other parts of northern Alberta.

Milt G. Pahl

Milt G. Pahl, M.B.A., P.Econ.
Director, Alberta Oil Sands
Environmental Research Program

ACKNOWLEDGMENTS

The authors would like to thank the following people for their contribution to the Stackwall Project:

Mr. Gorman Halfe
Mr. Henry Sparklingeyes
Mr. Edgar Sparklingeyes
Mr. Doug Davidson
Mr. Dean Petersen
Mrs. Carol Boyle

and especially Mr. Dirk Hadler who helped in all aspects of the project from beginning to end and, with his encouragement and decision-making assistance, made the work very enjoyable.

Photography by D.B. (Dirk) Hadler.

alberta canada

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

STUDY AREA

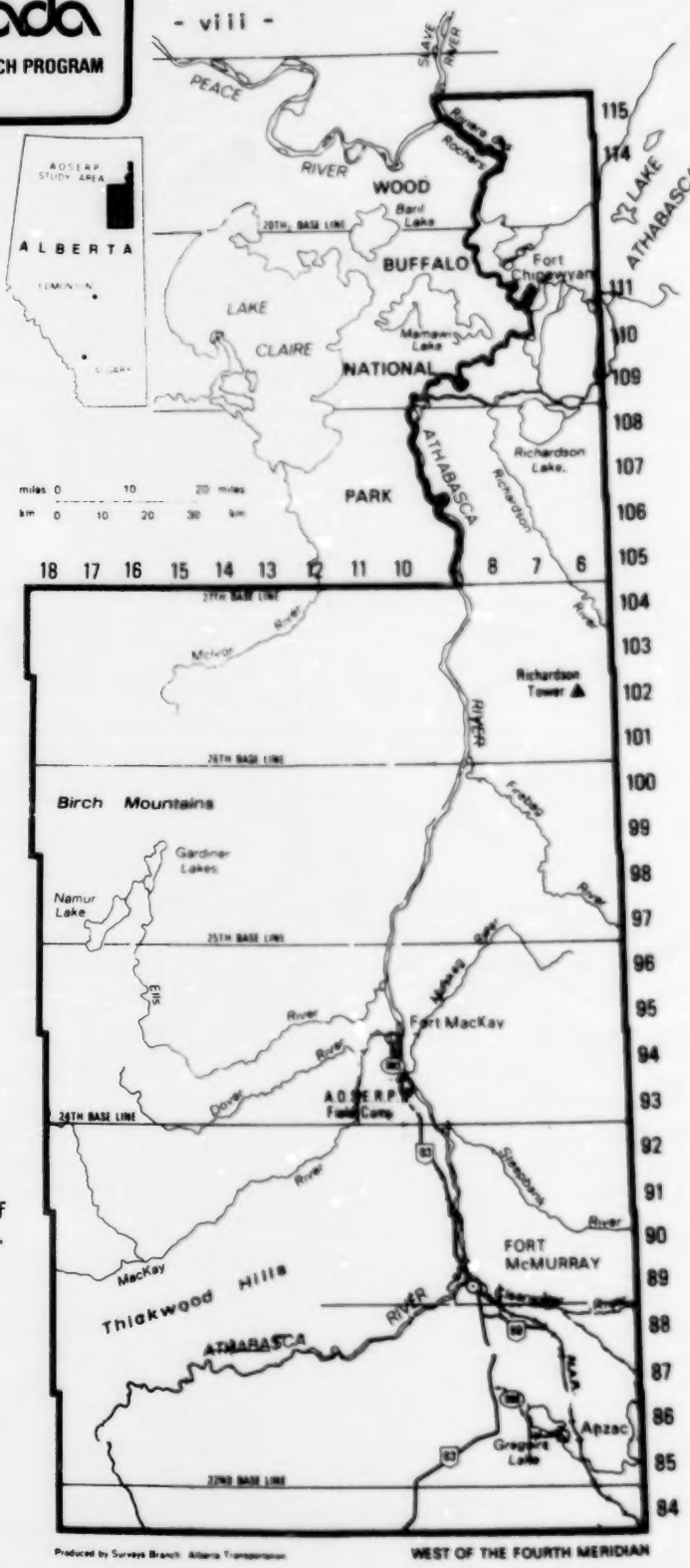
AOSERP STUDY AREA
ALBERTA
PEACE RIVER
SLAVE RIVER
WOOD BUFFALO NATIONAL PARK
LAKE CLAIRE
ATHABASCA
LAKE ATHABASCA
Fort Chipewyan
Richardson Lake
Richardson Tower
Birch Mountains
Gardiner Lakes
Namur Lake
Fort MacKay
AOSERP Field Camp
FORT McMURRAY
Thickwood Hills
Apzac
Gregoire Lake
miles 0 10 20 miles
km 0 10 20 30 km
18 17 16 15 14 13 12 11 10 8 7 6
115 114 111 110 109 108 107 106 105 104 103 102 101 100 99 98 97 96 95 94 93 92 91 90 89 88 87 86 85 84
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FIGURE 1. Location of the AOSERP study area.

HOUSING FOR THE NORTH -- THE STACKWALL SYSTEM

CONSTRUCTION REPORT -

MILDRED LAKE TANK AND PUMP HOUSE

by

R. PATTERSON and A. M. LANSDOWN

Northern Housing Committee
Faculty of Engineering
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Winnipeg, Manitoba

for

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

December 1976

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1. INTRODUCTION

The Northern Housing Committee was asked by Alberta Oil Sands Environmental Research Program to supervise construction of a stackwall structure to enclose a 5,000 gallon tank (the storage vessel for the water supply at the AOSERP research facility at Mildred Lake, Alberta) and the necessary accessory equipment.

The stackwall type of construction was chosen for a number of reasons:

1. The high insulation value of correctly constructed walls lowers the overall operating costs of the building and equipment;
2. The construction technique is labor intensive and thus a large percentage of expenditures can be channelled to man-hours as opposed to capital oriented machine-hours;
3. The use, where possible, of indigenous materials reduces the capital output for materials.

This report will outline the construction phases, describe and analyze the techniques unique to this type of construction and, using the collected data, calculate certain parameters for future reference.

It is important to keep in mind that the majority of construction was done in sub-zero temperature, the distance travelled for supplies was large, and most equipment was purchased exclusively for the stackwall. These aspects had some influence on the overall efficiency of the construction operation and, therefore, any calculation, observation and conclusion presented will refer to this particular structure, i.e. the Mildred Lake Research Facility structure, and should be used with caution, not regarded as general characteristics.

2. CONSTRUCTION

The four main phases of construction were: log gathering, cutting and sorting; wall construction; door and window construction; and roof and ceiling construction.

2.1. LOG GATHERING, CUTTING AND SORTING

The collection of the necessary logs started 28 October 1975 with a crew of three men. The logs, a variety of spruce, poplar and pine, had been cut and piled for approximately three years. They were located 12 miles from the construction site and were transported in a 3/4-ton truck with a load capacity of about 0.75 cords.

The cutting and sorting began while collecting and transporting continued. The crew was increased to four men, two collecting and two cutting. This procedure, using recorded manhour data, required 38.6 man-hours per cord (calculation Appendix 1). It includes the time involved in construction of a suitable jig (Photo 1) to enable more accurate cutting of logs with available hand-held chain-saws. The tolerance, measured by random sampling, was $\frac{1}{2}$". Logs within the range 23 3/4" to 24 1/4" were accepted, all others discarded. Also cut were the "sawn three sides" 8 x 8s (seen at the right in Photo 2). They were ripped at a nearby saw mill and delivered to the construction site in 12 foot lengths. For construction purposes, they were cut into 30" lengths and used as corner blocks (discussed later).

In total, 10.6 cords of logs and 288 lineal feet of 8 x 8s were cut, costing a total of $1,706 (calculation Appendix 1). In terms of price per cord of wood used in construction, the figure would be $160 per cord, and in terms of price per square foot of wall area (materials only, no labor) the figure would be $1.71. The labor-to-material cost ratio is 1.7.

2.2. WALL CONSTRUCTION

Prior to the actual laying of logs to form walls, the foundation, comprised of a network of railway ties, was accurately placed surrounding the previously-positioned water tank. The railway ties network was 36 x 16 feet and was made up of a pair of ties running parallel 24" apart, outside measurement, and interconnecting at the corners. The foundation was squared by a right-angle triangle method and covered by polyethylene (Photo 3).

Secondly, the building materials and equipment needed in wall construction were transported to the site. Included were 200 cubic feet of wood shavings (background Photo 3) and the first of many loads of hand-shovelled sand from a nearby pit. Also obtained, in anticipation of colder weather conditions, was a 1,000 board foot bundle of 2 x 4s to be used in the construction of a polyethylene enclosure, 40 feet long, 28 feet wide and 10 feet high, in order to cover the building and provide a small working area. (Photo 3 shows the enclosure partially completed and Photo 4 shows it completed.) The enclosure was initially heated by a small 100,000 BTU/Hr propane heater during the night; however, as average temperatures dropped, a larger 350,000 BTU/Hr heater and accessory generator were required almost continuously.

The initial wall construction was done by a crew of six. One mixed mortar (ratio 5:2:1: 5 sand, 2 cement, 1 lime) in a gasoline powered mixer; another hauled the mortar by wheelbarrow to the various locations. In addition, he supplied the builders with sufficient logs, 8 x 8 blocks, and shavings so work could continue uninterrupted. Two worked on corners, which involved laying the mortar on the foundation and placing two 30" 8 x 8 sawn-three-sides blocks 24" apart (outside measurement). Then more mortar was applied between the blocks' exposed faces and a log inserted along with shavings[1] to fill the inner gap. Next, mortar beads were placed along the edges of the already positioned blocks and two more blocks were placed perpendicularly to them. Then a log and shavings were again placed in the gap and the process continued (Photo 5).

Once the corners were built up, log layering could proceed. This entailed laying a bead of mortar along the foundation, approximately 3" on the inside and outside edges of the ties, then filling the gap with shavings. A log was then placed in position and another bead of mortar applied on that log's inside and outside edges. Shavings were packed in that gap and another log positioned. This was done, of course, in rows along the entire length of the wall, using larger diameter wood at the base of the wall (Photo 6).

---

[1] The shavings were mixed with hydrated lime to prevent insect infestation - approximately one shovelfull of lime per wheelbarrow of shavings.

The fact that the corner construction was allowed to proceed ahead of log-laying enabled the two men laying logs to use a string line, which kept the wall section plumb and straight, with the corners as end points (Photo 5 - note masonry clip on the fourth layer). The corners were set level and plumb as each layer was added, and the mortar was allowed to set before the corners were used as reference end points. Upon setting, the mortar was finished with a masonry jointer to a depth of 1/4" into the surface of the wall, thus accenting the log composition of the wall (Photo 9 shows the partially finished outer wall).

This type of corner construction and string line proved to be very efficient since it allowed construction of individual walls as opposed to having all four walls built up simultaneously, as required in other construction methods. The south and east wall were built first, because problems of mortar transportation would have been encountered if the north and west walls had been built first. Both the south and east walls were difficult to work on because of the limited working space in the enclosure at those points. An interesting comparison was carried out on the south wall (Photo 15). Note the lower portion of the wall where consistent diameter logs were used. The string line kept the wall plumb and maintained the row level. In the upper portion of the wall, the log placement was random and the string line was used simply as a plumb and straight line reference. Extra manhours are needed for the first method. We found that the extra time taken to obtain consistent diameter logs and maintain level rows was not rewarded with an improved overall appearance. Using random log selection construction was appreciably faster and no adverse construction problems resulted.

The east wall construction included the placement of the window and door frames. These were constructed from rough sawn 2 x 6 spruce. The door frame was four 2 x 6s set side by side with a dimension of 7' 2" by 2' 10" inside measure. The window frame was three 2 x 6s set side by side with a dimension of 2' by 2'. The window frame was placed flush with the outside wall but set 6" from the inside wall surface. The door frame was flush with both inside and outside wall surfaces. Both frames were cross backed (Photo 7) to avoid warping and twisting. Note that the door frame was set on the foundation while the window frame was placed at a height to allow a common set of lintels to be used for both

door and window (Photo 9). Also note (Photo 7) the extended nails in the frames, used to bind the frames to the mortar as the wall was built around them.

The next step was to place the door and window lintels, which were ripped-three-sides spruce logs anchored into the mortar wall with "extended" nails (the inside lintel is shown at the top in Photo 8, the outside lintel in Photo 9). The window sill was made of a 4 x 4 load divider (Photo 8). The outside window sill had a drip edge cut by chain saw tip (Photo 9).

The top plate was placed next. The west and east walls had 2 x 4s placed on the inner and outer edges, also anchored by "extended" nails. For the south and north wall, the top plates were a pair of 8 x 8 sawn-three-sides timbers running parallel on the wall edges. These plates are shown on the east wall (Photo 17) and the west wall (Photo 13). Large top plates on the east and west walls were required to support the great weight of the stackwall gable.

The final step was to construct the gable ends. For this portion of the stackwall, no shavings were placed in the gap because a high insulating value was not required. Special enclosures were required, however, to attempt to maintain an above-freezing temperature for the mortar curing process. Finally, a 2 x 4 was placed on edge and anchored along the 7/12 slope of the constructed gable to act as a nailing member parallel to the roof trusses (seen on gable Photo 10).

In total, the wall construction, including the preparation and subsequent clean-up of mortar from finished work, required 1,247 manhours. In terms of manhours per square foot of wall, calculations are: 1.25 man-hours per square foot (Appendix 1) or 0.80 square feet per manhour. The total cost of the wall construction phase was $4,983.63. In terms of cost per square foot, it was $5.01 per square foot. The ratio of labor to material cost was 1.9.

Once the stackwall work was completed and the mortar well along on its curing process, the polyethylene enclosure was removed and the 2 x 4s used in the door and roof truss construction.

2.3. DOOR AND WINDOW CONSTRUCTION

The door and window construction is unique in that the units were constructed on site more economically than "factory-produced" units. The double door and triple-pane window have performed very well to date and definitely should be considered for future projects.

As previously explained, the frames for the doors and windows were placed within the east wall during wall construction (Photo 8). It was decided that a two-door system be employed--one non-insulated outside door and one well-insulated inside door. Both were made windproof by placing polyethylene between the 1 x 8 layers. The outside door was made of 2 x 4s flatside, and 1 x 8s. The 2 x 4s were nailed in a rectangular form, with dimensions slightly less than the rectangular frame opening. Then 1 x 8s were nailed on the outside, long enough to cover the 2 x 4s and the frame itself. Polyethylene was placed on the inside of the rectangular form and 1 x 8s were nailed in place, forming the second side of the door (Photo 14).

The inside door was also made of 2 x 4s, flatside, and 1 x 8s. The 1 x 8s covered the 2 x 4 rectangle on both sides, and the gap was filled with discarded Fibreglass insulation from the AOSERP research trailers. The door fit entirely within the outer frame, flush with the inner wall surface. The 24" depth of the 2 x 6 frame served as a storm porch in that the outer door could be shut before the inside door was opened and vice versa. This stopped the flow of cold or warm air.

Both doors were hung by triple gate hinges and planed to fit more precisely. Then a propane torch was used to flame the wood, to prevent shrinkage and rotting. (The doors are shown in Photos 14 and 15; the inner insulated door is leaning against the structure.)

The window was constructed within the already positioned frame, entirely on the middle set of 2 x 6s of which the frame was made (Diagrams 1 and 2). (Also see Photo 8 for view of frame construction.)

For the window, quarter-round trim was nailed and sealed on the outer perimeter of the middle 2 x 6s. The sealant was applied to the quarter-round's inner face and the window glass placed against it. Further quarter-round was then placed on the inner face of the glass and sealed against it, then nailed. Thus, one pane was sealed around its perimeter

on both sides of the middle 2 x 6s. This procedure was repeated twice, forming independent panes of glass surrounded by quarter-round. (Diagram 2)

The door and window construction, as described, cost a total of $445.04: $375.15 labor, $69.89 materials. Compared to $700.00 for materials in the factory-built case, this is a considerable saving. The labor to material cost ratio is 5.4.

2.4. ROOF AND CEILING

The roof and ceiling were constructed in a conventional manner with a few minor differences.

The trusses were constructed from the 2 x 4s used in the temporary enclosure. They were all built on the ground according to specifications, lifted and nailed into place on 24 inch centers. It is important to note that when the top plates were anchored, they were as level as possible so that the trusses could be constructed identically and not individually to compensate for any differences in elevation. Once the trusses were nailed in place, they were braced with random diagonal 1 x 8s, and the ceiling was started.

For the ceiling construction, the horizontal members of the trusses were used for the nailing member on which 1 x 8 ribbing could be placed at 24 inch centers perpendicular to the trusses. The 1 x 8s were also placed along the horizontal members to complete the ceiling ribbing. This ribbing formed a network on which 4 x 8 sheets of 3/8" plywood were nailed to sheath the ceiling. Each sheet was secured by eighty $1\frac{1}{2}$" galvanized nails. This large number of nails in the plywood insured firm support for the 18" of shavings to be placed in the attic. Then 1 x 8s were placed on the upper edge of the trusses' horizontal members, in positions where the lower 1 x 8 ribbing had not been located. This further supported and distributed the weight of the shavings.

The roof was sheathed with 1 x 8 and 1 x 6 lumber (Photo 11) with the gable ends extended 2 feet to form the overhang (Photo 13). As the roof sheathing neared completion, the shaving material (Photo 12) was shovelled into the attic and evenly distributed at a depth of 18 - 20". The roof was then tar-papered with overlapping 24" strips bottom to top, and subsequently covered in cedar shakes using an overlap of 9" (Photo 13).

The blocking at the top plate, between the trusses, was completed using 1 x 8 lumber. Screening was used at intervals of 9 feet to replace the blocking (Photo 16) and complemented the gable end vents. During the winter when the attic air movement is not critical, the screens could be closed by redistributing the shavings over them.

The building was completed 19 December 1975 and, to date, with the 200,000 BTU/Hr propane heater, has maintained a relatively constant inside temperature.

Data are being collected to allow an estimation of the overall thermal insulating value of the structure. Preliminary calculations (Appendix 1) indicate that the wall's overall resistance is at least R18.

3. COSTS

The details of costs and cost calculations are given in Appendix 1. The Basic Costs are summarized below in Table 1, and Unit Costs in Table 2.

TABLE 1. Basic costs

Wage rate: Regular: $2.25 per hour
Overtime: $4.90 per hour

Operation	Labor		Materials and Equipment Cost	Total Cost
	Man-hours	Cost		
Woodcutting	409	$1,076.60	$ 629.74	$ 1,706.34
Wall building	1,247	3,293.35	1,690.28	4,983.63
Door and window	142	375.15	69.89	445.04
Roof and ceiling	580	1,940.75	1,294.48	3,235.23
Materials common to all phases	-	-	213.01	213.01
Total	2,378	$6,685.85	$3,897.40	$10,583.25
Stock Retained	-	-	($487.05)	($487.05)
Net cost of building				$10,096.20

TABLE 2. Unit costs

Operation	Area (square feet)	Man Hours per sq. foot	Cost per sq. foot	
Woodcutting	995	0.41	$ 1.71)	$6.72
Wall building	995	1.25	5.01)	
Door and window	-	-	-	
Roof and ceiling	1,285	0.45	2.51	
Total building (mean area)	476	5.00	$21.21	

4. CONCLUSIONS

From the evidence available to date, some tentative conclusions about heavy stackwall structures can be made:

1. With care taken over details such as corners, overhangs and treatment of openings, the appearance of a stackwall building is very pleasing.
2. Such a building can be built with relatively unskilled labor, provided supervision is available and care taken.
3. A high proportion of the total cost can be expended locally.
4. The overall cost per square foot of structure, after taking into account smallness of the building (high wall/floor area ratio) and adverse operating conditions at Mildred Lake, appears competitive with conventional forms of construction.
5. The thermal resistance of the walls appears to be close to the theoretical R20 to R25 predicted for fully dry walls.
6. The building appears to be durable and relatively maintenance-free (except for caulking in Fall, 1976). However, longer-term observations must be made before this can really be established with confidence.

Overall, the Northern Housing Committee feels that the experimental building at Mildred Lake has been successful in demonstrating a labor-intensive method of construction, and will provide useful information on performance of such a structure over the years. It is hoped that it might provide some stimulus to others in the Mildred Lake area who may wish to undertake some "sweat equity" building projects, especially housing.

APPENDIX 1.

CALCULATIONS

LABOR COST

WAGE RATES: Regular = $2.25/hr.
Overtime = $4.90/hr.

CONSTRUCTION PHASES:

Woodcutting	409 Man Hours	
	350 Regular - 350 x $2.25 = $787.50	
	59 Overtime - 59 x $4.90 = 289.10	$ 1,076.60
Wall Building	1,247 Man Hours	
	1,063 Regular - 1,063 x $2.25 = $2,391.75	
	184 Overtime- 184 x $4.90 = 901.60	3,293.35
Door and Window	142 Man Hours (includes rough frame construction)	
	121 Regular - 121 x $2.25 = $272.25	
	21 Overtime - 21 x $4.90 = $102.90	375.15
Roof and Ceiling	580 Man Hours	
	525 Regular - 525 x $2.25 = $1,181.25	
	155 Overtime - 155 x $4.90 = 759.50	1,940.75
Total Man Hours:	2,378	
Total Labor Cost		$ 6,685.85

BUILDING MATERIALS AND EQUIPMENT

CONSTRUCTION PHASES:

Woodcutting	Bar and plugs	$ 45.00	
	Saw equipment	49.80	
	Gas for saws	20.77	
	Plugs	15.05	
	Saw rental and depreciation	80.00	
	384 miles @ 18¢/mile for 3/4 ton truck	69.12	
	8 x 8 "sawn-three-sides"	320.00	
	Delivery	30.00	$ 629.74

Wall Building	Truck Rental for hauling shavings	$ 47.00	
	Rent mortar mixer	220.00	
	Wheelbarrow and shovels	88.50	
	Heater rental	130.00	
	Generator for heater	220.00	
	Heater purchase	80.00	
	Polyethylene)	53.84	
	Nails) Enclosure	26.14	
	2 x 4s)	80.00	
	Propane	444.00	
	Cement	252.80	
	Propane bottle rental	48.00	$ 1,690.28
Window and Door	Handles	$ 1.34	
	Hinges	7.45	
	Wood	26.00	
	Glass and sealant	35.10	69.89
Roof and Ceiling	Truck rental to haul shavings	$ 78.20	
	Cedar Shakes	740.00	
	1 x 8 boards	70.00	
	2 x 4 boards	80.00	
	1 x 6 boards	180.00	
	Nails	26.18	
	Vents	12.10	
	Plywood	108.00	1,294.48
Miscellaneous	Building materials	$151.88	
	Common to all phases	61.13	213.01
Total Building Materials and Equipment			$ 3,897.40
Stock Retained	Harness	$ 22.09	
	Chain saw purchase	286.57	
	Axe	20.05	
	Safety equipment	68.95	
	Files	5.19	
	Hammer	7.50	
	Skilsaw	64.95	
	Aprons	4.00	
	Spade	7.75	$ 487.05

LABOR AND MATERIALS TOTALS

Woodcutting	Labor	$1,076.60	
	Material	629.74	$ 1,706.34
Wall Building	Labor	$3,293.35	
	Material	1,690.28	4,983.63
Window and Door	Labor	$ 375.15	
	Materials	69.89	445.04

Roof and Ceiling	Labor	$1,940.75	
	Materials	1,294.48	$ 3,235.23
Miscellaneous			213.01
Total Labor and Materials			$10,583.25

DIMENSION CALCULATIONS

Wall Area

$(36 \times 9.5 \times 2) + (12 \times 9.5 \times 2) + 2 \times \frac{1}{2}(16 \times 5.0) = 995\ FT^2$

Cords of Wood

995 FT^2 (Wall Area) x 1.5 FT (Wall Thickness) - 10% Area for Mortar
$= 995 \times 1.5 - 99.5\ FT^2 - 1{,}393\ FT^3$
$1{,}393\ FT^2 = 10.6$ cords

Using the above calculations, pertinent ratios can be determined. Data collected is allocated as described in discussion or conveyed in addition lists.

RATIOS

WOOD CUTTING

$$\frac{\text{Man Hours}}{\text{Cord}} = \frac{409}{10.6} = 38.6 \text{ Man Hours/Cord}$$

$$\frac{\text{Cost}}{\text{Cord}} = \frac{\$1{,}706}{10.6 \text{ Cords}} = \$160/\text{Cord}$$

$$\frac{\text{Cost}}{FT^2 \text{ unconstructed wall}} = \frac{\$1{,}706}{995\ FT^2} = \$1.71$$

$$\frac{\text{Labor Cost}}{\text{Material Cost}} = \frac{\$1{,}076}{\$\ 629} = 1.7$$

WALL BUILDING

$$\frac{\text{Man Hours}}{\text{FT Wall Area}} = \frac{1{,}247}{995} = \frac{1.25 \text{ Man Hours}}{FT^2}$$

$$\frac{\text{Cost}}{FT^2} = \frac{4{,}983.63}{995} = \$5.01$$

$$\frac{\text{Labor Cost}}{\text{Material Cost}} = \frac{3{,}293.75}{1{,}690.28} = 1.9$$

DOOR AND WINDOWS

$$\frac{\text{Labour Cost}}{\text{Material Cost}} = \frac{375.15}{69.89} = 5.4$$

ROOF AND CEILING

Roof Area

$2(40\ \text{FT} \times 11.2\ \text{FT}) = 901\ \text{FT}^2$ 1

Ceiling Area

$12 \times 32 = 384\ \text{FT}^2$

$1,285\ \text{FT}^2$

$$\frac{\text{Cost}}{\text{FT}^2} = \frac{3,235.23}{1,285} = \$2.51$$

$$\frac{\text{Labour Cost}}{\text{Material Cost}} = \frac{1,940.75}{1,294.48} - 1.5$$

COMBINING PHASES 1 AND 2

Wood Cutting and Wall Building

$$\frac{\text{Cost}}{\text{FT}^2\ \text{Wall}} = \frac{1,706.34 + 4,983.63}{995} = \$6.72$$

$$\frac{\text{Total Cost}}{\text{FT}^2\ \text{Floor Area (mean)}} = \frac{\$10,096.22}{14' \times 34'} = \$21.21$$

$$\text{Overall } \frac{\text{Labor Cost}}{\text{Material Cost}} = \frac{\$6,685.10}{\$3,897.40} = 1.72$$

WINTER CONSTRUCTION COST ESTIMATE

MATERIALS

Heater rental	$130.00	
Generator for heater	220.00	
Heater purchase	80.00	
2 x 4s	80.00	
Polyethylene	32.00	
Nails	20.00	
Propane	444.00	
Propane bottle rental	48.00	$ 1,054.00

LABOR

Polyethylene Enclosures

Main	65 Man Hours	60 Regular 5 Overtime
Gables	20 Man Hours	20 Regular

Hauling Propane

42 Man Hours 42 Regular

Heater Set-up and Maintenance

20 Man Hours 20 Regular

ESTIMATION

Man Hours Lost - Mortar Thawing, Setting and Finishing

27 Man Hours 27 Overtime

Total Labor

(60 + 20 + 42 + 20) \$2.25 + (5 + 27) \$4.90

= \$319.50 + \$156.80 = \$ 476.30

Total Winter Construction Cost Estimate \$ 1,530.30

NOTE: Worker inefficiencies due to cold are not included.

PRELIMINARY CALCULATIONS - HEAT LOSS

Heat Losses: Water
Ground
Roof
Walls

Assumed temps: $Ti = +64^{\circ}$ F

$To = -15^{\circ}$ F

Water: Tank: Length = 20 ft.
Diameter = 7 ft.

Avg. (R_{BL}) Air = 0.71

(R_{BL}) Water = 0.02

R - Steel = 0.00

R = 0.73 $\mathcal{U}$ = 1.37 BTU/hr/ft^2/$^{\circ}$F

Tank surface area = 517 ft.^{2}

Assume: T house = + $64^{o}F$

T water = + $40^{o}F$ $\Delta T = 24^{o}F$

Q water = (24)(1.37)(517) = 17,000 BTU/hr. when full.

If we assume tank is filled every 3 days with 4,000 gal. water, and this is raised to $64^{o}F$, then every 72 hrs. 4,000 x 10 x 24 = 960,000 BTU are absorbed by water, for an average of $\frac{960,000}{72}$ or 13,300 BTU/hr.

When tank is about ½ full to full, water will absorb heat at about 17,000 BTU/hr., then will taper off.

Therefore, conservative assumption is 13,300 BTU/hr. delivered to water. (Note: some heat will carry over between fills due to thermal mass of building also. However, such mass is small in comparison to that of water.)

Water: 13,300 BTU/hr.

Floor: Through ground

$$Q = 1 \frac{KS}{\pi} \Delta T \, Ln \left(\frac{\frac{B}{2} + tw}{tw} \right)$$

References 1TN-76/9
1TN-76/16

At Mildred Lake: 1 = 34 feet
B = 12 feet
tw = 2 feet
$\Delta T = + 64^{o} - (-15^{o}F) = 79^{o}F$
ks = BTU/hr. ft. ^{o}F

Hence Q = 1,534 BTU/hr.

Ground: 1,500 BTU/hr.

Roof and Ceiling

18" Shavings + 1" wood

Shavings	R = 2.22/in.:	18 x 2.22 = 39.96
Wood	R = 1.25/in.:	1 x 1.25 = 1.25
Air surface	R = 0.61/surface:	2 x 0.61 = 1.22
		R = 42.43

$$\mho = \frac{1}{R} = 0.024$$

Roof Area (mean) = 476 $ft.^{2}$

$$Q = (A)\ (\Delta T)\ (\mho) = (476)\ (79)\ (0.024) = 887 \text{ BTU/hr.}$$

Roof: 900 BTU/hr.

Losses through water, ground and roof = 15,700 BTU/hr.

Total losses = heater capacity = 20,000 BTU/hr.

Therefore Net (through walls, window and door) = 4,300 BTU/hr.

Wall Area, Mean = 995 $ft.^2$

Therefore heat loss = $\frac{4,300}{995}$ - 4.32 BTU/hr/$ft.^2$

$\Delta T = 79^{\circ}F$

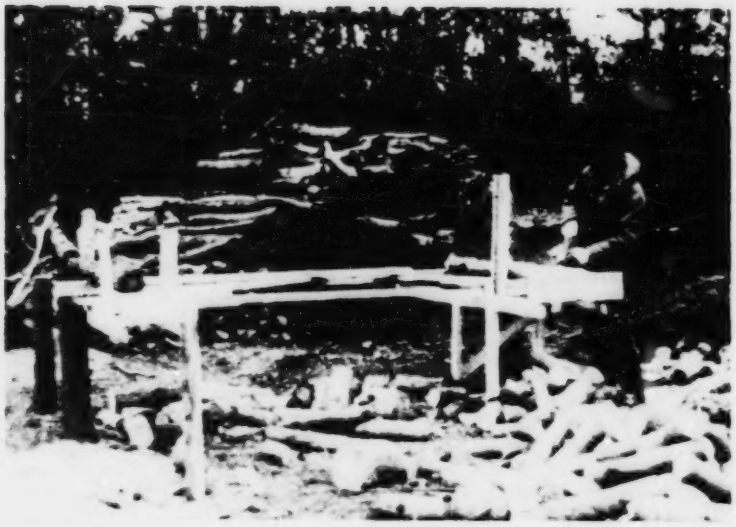
Therefore $\mathcal{U} = \frac{4.72}{79} = 0.055$ BTU/hr/$^{\circ}F$

$R = \frac{1}{\mathcal{U}} = 18.28$

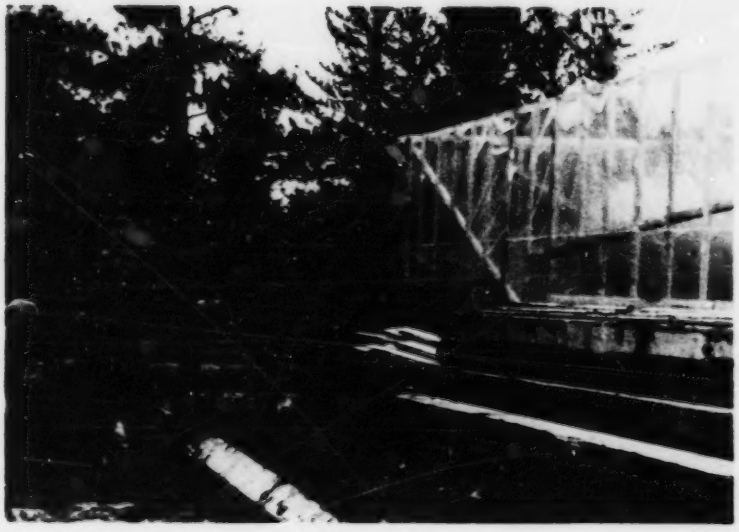
This is a lower limit, as ground may be wet, walls may still have some moisture in them, air infiltration has not been estimated, and effect of door and window has been neglected.

APPENDIX 2.

PHOTOGRAPHS



PHOTOGRAPH 1. Construction of a jig for cutting uniform log lengths.

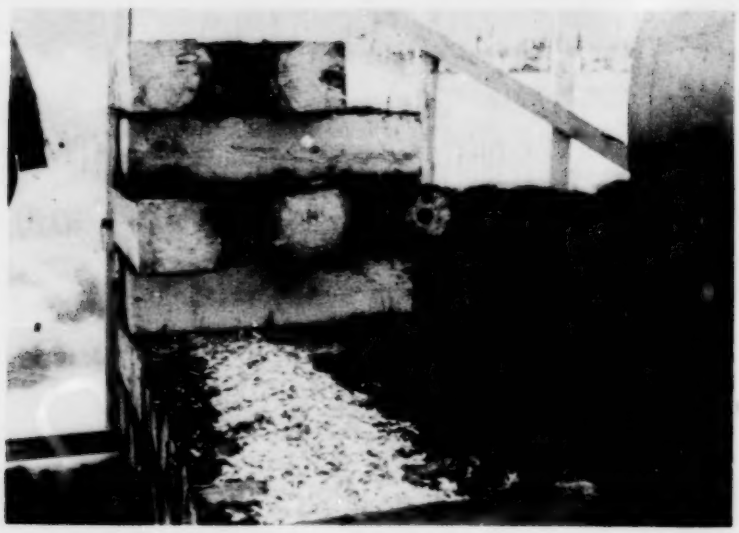


PHOTOGRAPH 2. Log pile, sawn-three-sides lumber, and exterior of polyethylene enclosure.

PHOTOGRAPH 3. Interior of polyethylene enclosure showing sawdust pile.

PHOTOGRAPH 4. Exterior of completed polyethylene enclosure.

PHOTOGRAPH 5. Corner block and partially-completed wall.



PHOTOGRAPH 6. Corner block and wall construction.

PHOTOGRAPH 7. Interior view of cross-backed door and window frames in place.

PHOTOGRAPH 8. Interior view of common lintel for door and window.

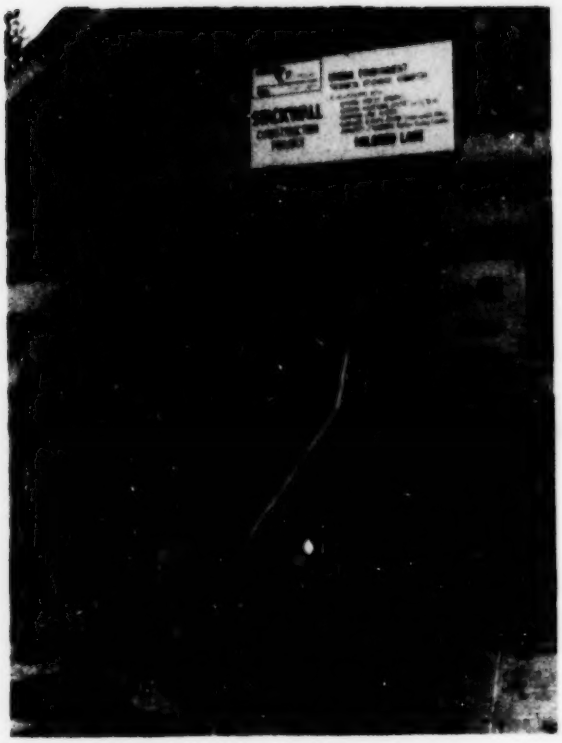
PHOTOGRAPH 9. Exterior view of common lintel for door and window, and window sill.

PHOTOGRAPH 10. Gable construction and enclosure.

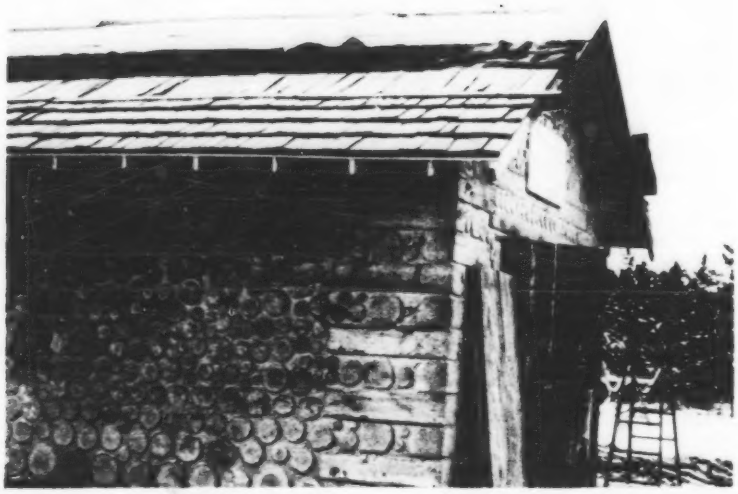
PHOTOGRAPH 11. Roof construction showing trusses and sheathing.

PHOTOGRAPH 12. Wood shavings pile used for insulation.

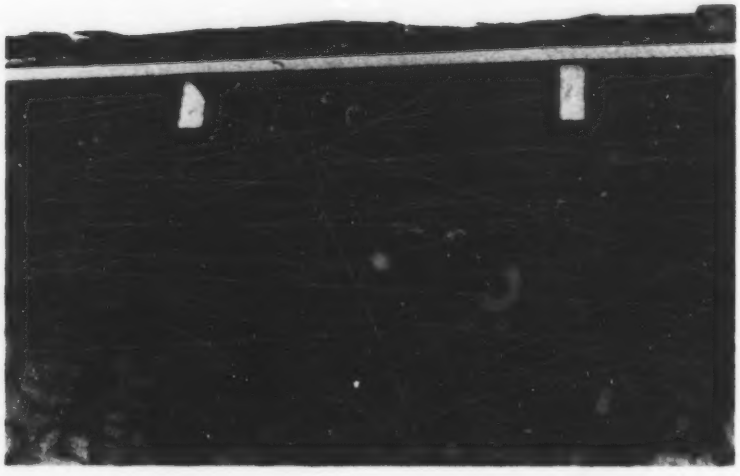
PHOTOGRAPH 13. Roof construction and shingling.



PHOTOGRAPH 14. Outside door construction.



PHOTOGRAPH 15. Roof construction and shingling, and doors (inner door leaning against structure).



PHOTOGRAPH 16. Venting at top plate, between trusses.

PHOTOGRAPH 17. Completed stackwall building.

APPENDIX 3.

SKETCHES

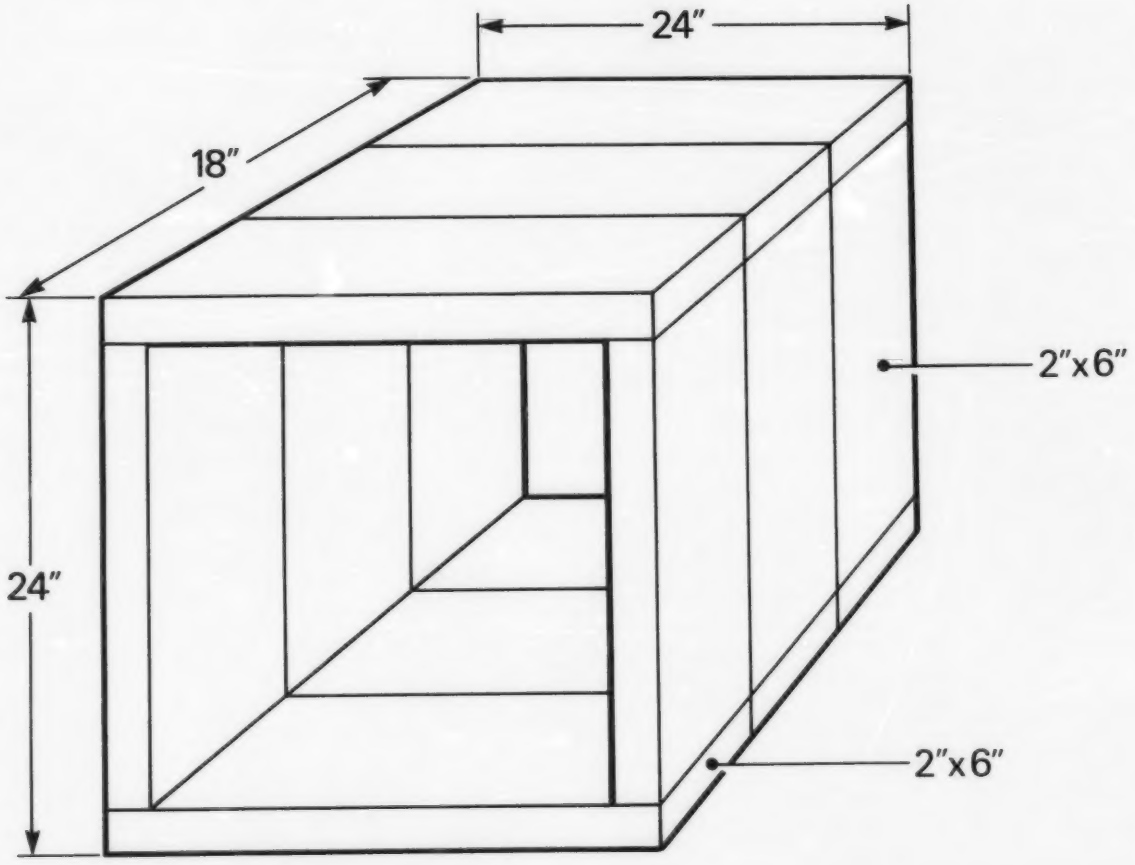


DIAGRAM 1. Window Frame

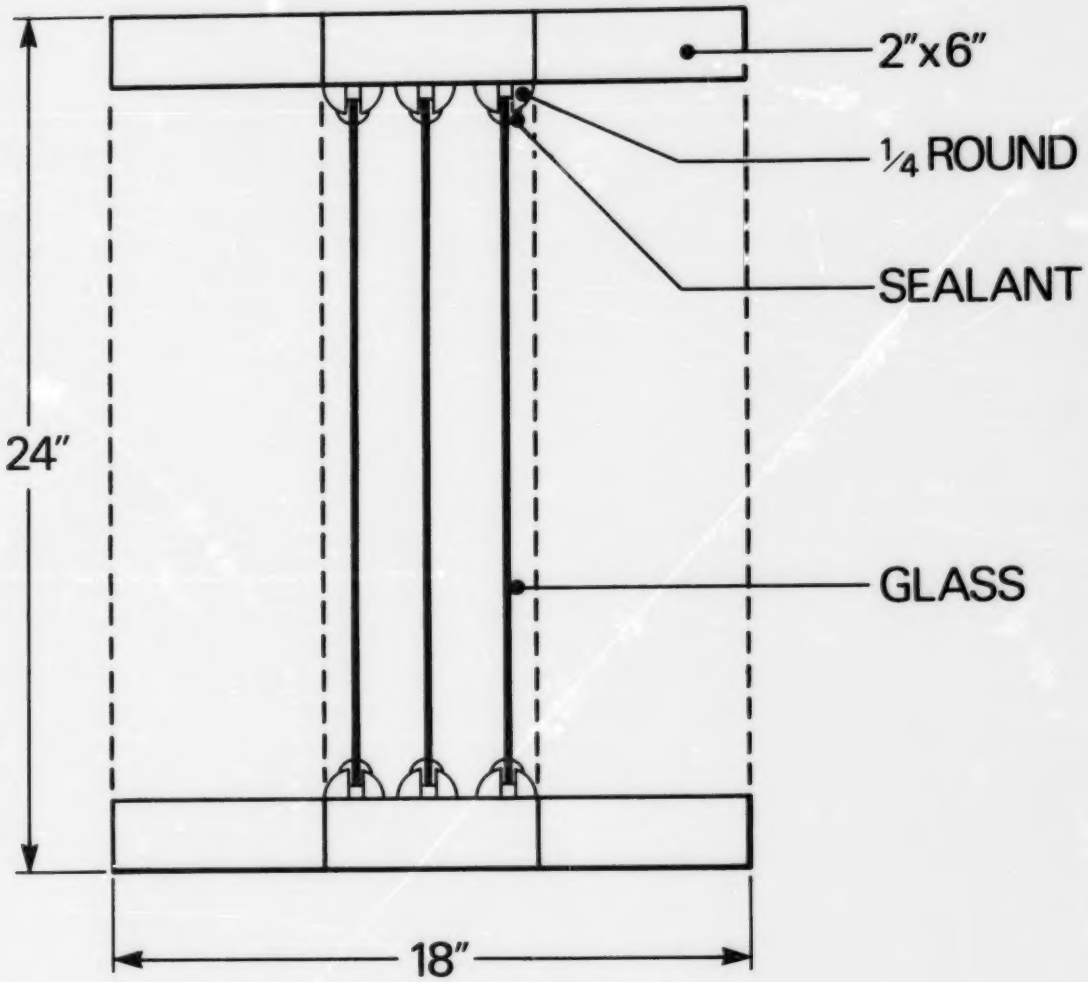


DIAGRAM 2. **Window Cross-Section**